

Sustainable Potato Cropping Systems

Summary

Comparisons of sustainable Best Management Practices, or BMPs (based on judicious inputs focusing on environmental and economic sustainability), with Maximum Yield Management, or MYM (based on “insurance inputs targeting maximum yield), were completed in 14 Pacific Northwest fields. The BMP approach proved to be financially advantageous in all but two fields in the trial. These results and the growers practicing BMPs were highlighted at three field days and in many workshops, publications, and radio/TV venues, resulting in significant on-farm changes in a large percentage (over 20,000 acres documented and many more planned) of Pacific Northwest potato fields.

Introduction

Potatoes (*Solanum tuberosum*) are an important food staple. The Pacific Northwest produces a significant amount of this important crop. As a result, potato producers are one of the largest consumers of agricultural chemicals in this region.

Water, soil, and food quality issues are prompting government agencies to encourage voluntary reductions in pesticide and fertilizer inputs. Otherwise, growers potentially face mandatory reductions and monitoring via the Environmental Protection Agency’s Total Maximum Daily Load (TMDL) and other related directives. Many water bodies have been identified as having contaminant concentrations above the criteria established by regulatory agencies. A few of the concerns related to farm chemical use are: 1) nitrate concentrations in ground water supplies, 2) phosphorus loading in surface waters, 3) pesticide residues in water supplies and food stuffs, 4) soil quality reductions related to depletion of beneficial organisms, 5) pesticide resistant organisms, and 6) farm worker exposure to toxic materials.

In addition to environmental concerns, the agricultural economy continues a trend downward, forcing growers to decrease production expenses in order for them to remain competitive. Pesticides and fertilizers comprise nearly 40% of average potato production costs. An informal assessment of potato production practices shows, however, that the majority of growers tend to over apply agricultural chemicals/fertilizers by 5 to 30%. This overuse stems from two problems: 1) a maximum yield with high input mentality and 2) intense cropping systems that do not take advantage of natural pest control and fixation/recovery of existing nutrients. These appraisals also show that growers are aware of the more conservative guidelines, but choose to over apply because of previous successes and a lack of confidence in the real-world application of research data.

Unfortunately, most growers do not realize the economic and environmental ramifications of the production practices stemming from this over-use mentality. One-on-one economic analysis results in the grower’s increased awareness of the financial losses, but also a continued reluctance to break tradition. Most growers are more likely to follow the examples of other successful growers rather than following research/government recommendations/guidelines.

Several SARE and other research/extension projects provide the foundation for this project. This project promotes best management practices (BMPs) for sustainable potato production elucidated in numerous individual research efforts partially listed below.

Several SARE-funded projects provide valuable information to be used in this project. Everts (2000) is currently working on management alternatives to chemical control of root knot nematodes. Several other researchers are or have looked at alternatives for nematode control, since there are many bio-controls available that provide options that may be more environmentally and economically sustainable (Eberlein, 1999; Murphy, 2000; Porter, 2000; Porter, 1993; Safir, 1991; Stark, 1991). Alternative disease (Eberlein, 1999; Chun, 1995; Stark, 1991), insect (Murray, 1996; Murray, 1995; Porter, 1993; Smilowitz, 1992; Stark, 1991), and weed (Eberlein, 1999; Stark, 1991) suppression techniques have also been evaluated. Murphy (2000) worked toward the concept of promoting a sustainable potato production system. This project is unique, however, as it focuses on the integration of proven BMPs for the entire cropping system that will not eliminate non-biological controls, but will result in a significant reduction in fertilizer and chemical inputs for a large number of growers.

A multitude of research and extension efforts have recently been pooled into a Potato Production Systems book (Stark and Love, 2003) published by the University of Idaho. Washington State University is also currently working toward a Best Management Practices for Potato Production publication. Many other publications identify the management practices that will be promoted in this project (Dean, 1994; Zehnder et. al, 1994; Rowe, 1993; Flint, 1986).

In addition, the University of Idaho Potato Cropping Systems Program conducted a study of agricultural producers to assess the adoption level of sustainable BMPs that have been shown to work (Hopkins et al., 2006). The majority of growers evaluated did not utilize these new strategies.

With regard to new fertilizer recommendations (Stark and Love, 2003), most growers over apply phosphorus and potassium and, to a lesser degree, nitrogen. Upon further inquiry, two apparent facts emerged. First, growers were aware of the new fertilizer guidelines. Second, growers were reluctant to alter their practices because of comfort in their previous success in growing potatoes and a feeling of group belonging with neighboring growers that were reluctant to change. There are other essential elements that are frequently over applied as well. In most cases, over application of nutrients other than nitrogen and phosphorus does not pose a direct environmental risk, but does represent a waste of the farmer's money, as well as the natural resources required for fertilizer manufacturing.

In addition to fertilizers, pesticides are also frequently over applied in potato production. Despite efforts to move growers toward integrated pest management practices, the prevailing attitude of near zero tolerance to the presence of pests remains. When asked if they based pesticide applications on economic thresholds, most growers indicated that they were aware of the concept, but they preferred to apply pesticides as a safety net rather than risk losing their investment in the crop. Most growers have experienced significant crop losses and failure. The anxiety from distressing over potential future failures is no small obstacle to overcome when attempting to get growers to adopt practices for which they are not familiar and have no confidence.

An illustration of this is the lack of widespread adoption of using green manures as an alternative to using fumigants. Several studies have shown that certain green manure crops have the potential to provide biological control of certain soil borne diseases, nematodes, and weeds (Araji and Hafez, 2000; Hafez and Sundararaj, 2000a; Hafez and Sundararaj, 2000b; Eberlein, 1999; Al-Rehiyani et. al., 1999; Al-Rehiyani and Hafez, 1999; Boydston and Hang, 1995). Despite this work, less than one percent of the acreage represented in the aforementioned survey used green manures in rotation with potatoes. A current SARE project titled "Advancing Sustainable Potato Production in the Northwest" experienced success in creating awareness, and a few growers have adopted these practices, but the greater part of them are reluctant to adopt practices that they view as risky.

The issues that inhibit growers from adopting BMPs, both real and imagined, played a major role in why many of the growers ignored potentially valuable information. When asked what would help boost their confidence in research-based BMPs, most growers indicated that the number one influence would be adoption by successful and respected growers. Ironically, many growers have successfully adopted some or all of the BMPs in question. Based on these findings, the best way to facilitate grower adoption may simply be to highlight potato producers successfully using BMPs.

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Objectives/Performance Targets

- 1.) Compile a written and a web-based guideline of Best Management Practices for Sustainable Potato Cropping Systems in the Pacific Northwest.
- 2.) Refine the existing Ag Input computer spreadsheet into a user-friendly, stand-alone computer program that empowers growers to make informed decisions regarding fertilizer and pesticide inputs based on economics and sustainability.
- 3.) Assess initial and ending level of adoption of best management practices (BMPs) through in-person appraisal of 40

producers' operations and a larger number of growers through the evaluation module of the interactive web-based guideline (see objective #1).

4.) Conduct on-farm field demonstrations with producers and publicize detailed case studies of these "model" growers' successful implementation of sustainable BMPs.

5.) Stage an annual "Advanced Potato Production Workshop" featuring BMPs and crop, nutrient, soil, water, and pest management fundamentals.

6.) Facilitate farmer-to-farmer roundtable discussions to discuss success experiences, as well as obstacles encountered, during the implementation of sustainable BMPs.

Materials and Methods

1.) Objective 1 was accomplished through review of all of the current BMP guides for potato production in effect for the Pacific Northwest and then working collaboratively with various scientists, agronomists, and growers in the region to publish a BMP guide.

2.) The Ag Input spreadsheet in Objective 2 was worked on but then abandoned during the course of the project to avoid duplication with a computer program published by the University of Idaho's Agricultural Economics and Rural Sociology department's Crop Enterprise Budget Worksheet (CEBW) program (Patterson, 2006). Efforts were made to work with the economist annually refining this program to integrate the BMP ideas into the use of this program.

3.) Objective 3 was accomplished through one-on-one survey with 38 growers at the beginning and ending of the project (the initial number of growers was higher, but was reduced by the end of the project due to some of the growers leaving the potato industry due to financial, health, or other reasons). The growers were randomly selected from a list of regional potato producers found in University of Idaho's Potato Conference data base. The growers were called by the project director in 2001 and asked to participate in the verbal survey. Among other questions, the growers were given a list of five BMPs covering a range of potato production disciplines. The five selected BMPs included: 1) applying fertilizer based on soil sampling and research-based recommendation tables, 2) planting seed pieces at a six-inch depth, 3) cultivating at or just prior to emergence, 4) measuring actual water use and cutting back irrigation during late bulking, and 5) applying protectant fungicides just prior to row closure and 7-14 days later with additional as-needed applications based on scouting and local pathogen pressure levels. The growers were asked if they were aware of the recommendations and if they had implemented these practices on their farm. These same growers were contacted in 2006, at the end of the project, and asked similar questions, as well if they were aware of this BMP project and how effective they felt that it had worked.

4.) Objective 4 was accomplished through fourteen potato field demonstrations/trials conducted at various locations across Idaho, Oregon, and Washington over four years (Table 1). Plot size was 40 ft. by 12 ft. (4 rows) with 10 to 12 in. in-row seed piece spacing.

Field selection criteria were based on an attempt to highlight "model growers" who best exemplified successful production and whose management coincided with research-based BMPs, with a maximum economic yield approach as a normal part of farm management. The cooperating scientists in each of the regions where trials were conducted were responsible for selecting the grower(s). Five replicates of two treatments, best management practices (BMP) management and maximum yield management (MYM), were established in randomized complete blocks (RCBD) in each field. This project is distinctive in that the treatments were not based on specific, controlled practices, but rather consisted of a comparison of two management approaches. There were many BMPs for growers to follow (Hopkins et al., 2006), but fertilizer and pesticide inputs were the focus of this project. In general, the cooperating "model growers" used the following practices with regard to fertilization and pesticide BMPs.

Pre-emergence fertilizer recommendations were based on reasonably intensive soil sampling and analysis with the amount of fertilizer applied derived from tables formulated from cooperative university and industry research (Lang et al., 1999; Stark et al., 2004). Typically, the amount of fertilizer recommended in these tables is for producing 90-95% of maximum yield and based on maximum economic yield (MEY). In-season fertilizer recommendations were based on petiole analysis, again with the fertilizer applied based on MEY research. Pesticide application philosophy was similar to the fertilization approach. Initial applications of herbicides, insecticides, fungicides, and fumigants were based on field history and expected pest/pathogen pressure. Additional applications were made only if scouting, sampling, and forecasting models indicated a need. The entire field was managed by the grower using a BMP approach, with little input from the cooperating scientists. As such, it was hoped that these fields would serve as a testament to the validity of BMPs.

A plot area within each field was set aside to compare BMP to MYM treatments. The BMP plots received the same treatments as the rest of the field. The MYM plots received additional fertilizer and pesticide inputs based on each field's unique circumstances. The decision to apply fertilizer and pesticides was made by the local cooperating scientist in cooperation with the grower and the advising agronomist(s). If a particular input being considered for its potential to increase yields was decided against by the BMP grower because previous research data indicated the cost would likely exceed the benefit, the input was then applied only to the MYM plots. For example, the ID1 field had a substantial number of apparent weed escapes. The grower was contemplating applying an additional herbicide application, but the grower's agronomist recognized that the emerged weed seedlings would probably be inhibited enough by the existing herbicide in the soil and, therefore, an additional application would not likely prove to be cost effective. The grower decided to follow this advice for the whole field. However, the near zero tolerance approach called for an herbicide application in the MYM plots. The grower's decision proved to be justified, as the weeds in the areas outside the MYM plots were only slightly worse, with the effect on yield not significant.

Each entire field, including both BMP and MYM plots, typically received at least: 1) fertilizer applications based on university recommendations, 2) seed treatment for pathogen control, 3) two-way tank mix or separate applications of two herbicides, 4) insecticide as a seed treatment or applied at hilling, and 4) two fungicide applications. Those fields having a longer growing season (western Idaho and Washington and Oregon fields) tended to receive proportionally higher input rates by necessity. The additional inputs for these longer growing season areas typically included one additional insecticide application and several fungicide applications.

The added inputs for the MYM plots in each field are listed in Table 2. A majority of the fields received additional pre-emergence or water-run fertilizer in the MYM plots with an average rate of: 47 kg-N ha⁻¹ (5 fields), 82 kg-P₂O₅ ha⁻¹ (11 fields), 68 kg-K₂O ha⁻¹ (11 fields), 45 kg-S ha⁻¹ (10 fields), 49 kg-Cl ha⁻¹ (8 fields), 6 kg-Mn ha⁻¹ (11 fields), 5 kg-Zn ha⁻¹ (6 fields), 1 kg-B ha⁻¹ (5 fields), 1 kg Fe ha⁻¹ (2 fields), and 0.5 kg-Cu ha⁻¹ (2 fields). In addition, all of the Idaho fields and two of the Washington fields had one or two additional foliar nutrient sprays (generally combined with fungicide sprays) in response to marginal petiole nutrient concentrations. The foliar nutrient sprays ranged from single element to complete nutrient regimes. The Oregon fields did not have foliar nutrient sprays, but had water-run fertilizers instead.

In addition, the MYM plots in all of the Idaho and one of the Washington fields received one to three additional foliar fungicide applications. Because the growing season in the Columbia Basin of Washington and Oregon is typically longer than it is in Idaho, the number of fungicide applications made throughout the season is usually greater. This is a good example of how BMPs may vary by region. The pathogen management BMP for fields with long growing seasons regularly requires frequent fungicide applications, whereas growers in short season areas may be able to avoid frequent fungicide applications, especially when humidity/rainfall and local pathogen pressure is low. As a result, the BMP growers in south central- and eastern-Idaho applied fungicide only one to three times, giving an opportunity for additional applications on the MYM plots. Alternatively, the BMP growers in Oregon and Washington applied fungicide more frequently and this resulted in a lack of opportunity to apply additional fungicide in the MYM plots. In contrast to fungicide applications, the differences between BMP and MYM treatments for the other pesticides were minimal. Only one field had additional herbicide, one had supplementary nematicide, and two had additional insecticides in the MYM plots.

For the MYM plots, water-run and foliar applications of fertilizers and pesticides were applied with compressed gas back-pack sprayers calibrated to deliver label rates with < 5% variation between nozzles. Foliar sprays were applied with manufacturer recommended spreader/stickers to enhance foliar absorption. Water-run treatments were simulated by application immediately prior to overhead irrigation and in the early morning to avoid the drying of product on leaves. Dry fertilizer was applied evenly across each plot with a spinning broadcast hand spreader and then incorporated as a part of the normal field operations (bedding or hilling). Soil samples, to determine pre-emergence fertilizer rates, were taken randomly throughout the field (~15 cores per field) to a 12 in. depth. The fourth fully emerged petiole was collected from the top of ~40 plants across each treatment to determine in-season nutritional needs. Soil samples were submitted to a commercial laboratory for drying and analysis using approved methods.

Tubers were harvested from 20 ft. of the center two rows of each plot, by hand or machine, to determine yield within one to seven days of the grower's harvest date. Tuber fresh weights were determined gravimetrically. Marketable yields were determined by combining all US No. 1 and US No. 2 size grades. US No. 1 and, in some cases, US No. 2 tubers were separated into various size categories. Break points for size categories included: 4, 6, 8, 10, 12, and/or 14 oz. Cull yields were determined by combining all undersized (< 4 oz.), malformed, and tubers with external physiological, pest, or pathogen related defects. A random sampling of each of the tuber size categories over 4 oz. was saved for specific gravity analysis and internal defect evaluation (minimum of eight tubers per plot). A composite of tubers was used to determine tuber specific gravity using the weight-in-air/weight-in-water method (Kleinschmidt et al., 1984). Internal defects were determined by

inspecting a sub-sample of at least eight tubers from each plot and cutting each tuber in half along the longitudinal axis.

Gross crop values were estimated by using five year average regional processing potato prices of \$4.95 cwt-1 for marketable potatoes and \$1.75 cwt-1 for cull potatoes. This simplified, least common denominator approach in determining crop value (as compared to using price incentives for size, specific gravity, etc.) was used because of the diversity of market scenarios faced by the growers across regions and time during the project. Although the main emphasis presented here is the non-incentive adjusted pricing, incentive adjusted scenarios were also applied to the yield data and presented in part below.

Net crop value was estimated by subtracting the cost of the added MYM inputs from the gross crop value. The cost of added inputs was estimated by determining the average prices of the inputs and custom application charges at the time of application. Field response was determined by subtracting the yields and crop values of the BMP from the MYM plots.

Differences across treatments were determined by ANOVA, with the PROC GLM procedure in SAS software (SAS Institute 1990) with significance indicated at $P < 0.05$ unless otherwise noted. Statistical analysis was conducted on yield and gross/net return parameters by combining individual field data with treatment and field location as dependent variables. Yield and gross/net return parameters for individual fields were analyzed separately when the treatment by field location interaction was significant.

5-6.) Objectives 5 and 6 were achieved by conducting several public field days located at some of the model grower's fields, as well as at other grower meetings and with various extension and popular press publications. In addition, growers expressing interest in adopting BMPs were provided one-on-one assistance in evaluating their operation.

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Results and Discussion/Milestones

1.) The Best Management Practices (BMPs) for Sustainable Potato Production regional publication has been available as a web-based publication (<http://extension.ag.uidaho.edu/bhopkins/Projects/bmp.htm>) with over 300 "hits" and informal printing and distribution to over 100 growers/agronomists. This publication has been revised in cooperation with eleven potato scientists from three different states representing the following disciplines: agronomy, crop science, soil science, pathology, entomology, weed science, nematology, physiology, irrigation engineering, and economics. This publication focuses on practices that enable growers to be economically viable while maintaining sustainability of the farm and soil and water resources. This publication is currently being reviewed and will be published as a Pacific Northwest Regional Extension Bulletin.

2.) Although it was originally planned to revise an existing Ag Input computer spreadsheet into a more user-friendly, stand-alone electronic tool that empowers growers to make informed decisions regarding fertilizer and pesticide inputs based on economics and sustainability. However, it was recently decided to abandon this spreadsheet and, instead, work with a University of Idaho Ag Economist, Paul Patterson, to use a more versatile Crop Enterprise Budget Worksheet software tool to accomplish the same purpose. This software has been adopted by the University of Idaho as a quasi official tool that is used to assist growers in evaluating production economics. Dozens of copies of this software on cd have been distributed to

growers and agronomists. Three workshops were conducted in February 2006 in which growers were presented the results of this project, given an example BMP (lengthening the time between potato crops), and then shown how to use the software to assess the financial ramifications (both good and bad) of adopting this BMP. Over 70 growers attended these workshops.

3.) Initial and ending level assessment of grower compliance with BMPs has been completed with thirty-eight growers. Initial level of adoption ranged from 38 to 72% with an average of 52%. Ending level of adoption ranged from 50 to 86% with an average of 66%. Furthermore, most all of the growers planned further changes in practices in future years. Further assessment is planned with these, as well as the other growers attending the workshops described in number 2 above.

4.) A total of fourteen field demonstrations from 2002 through 2005 highlighted ten "model" growers in Idaho, Oregon, and Washington that successfully follow Best Management Practices (BMPs). These growers are unique in that they produce high yields of good quality potatoes without excessive inputs of fertilizer and chemicals. In addition to the demonstration aspect of this project, formal research trial comparisons were made in each of the fields by comparing the growers' standard practices (BMP) with plots receiving relatively higher rates of fertilizer and pesticides. Marketable, cull, and total yields for BMP and MYM treatments were statistically equivalent when evaluated across all fields (Figure 1 shows marketable and cull; total is determined by addition/subtraction of marketable and total). In addition to the combined analysis, each individual field was analyzed separately due to the significant interaction between field location and treatment. MYM treatment resulted in significant increases in total and marketable yield for three fields (ID7, OR1, and WA1) and significant decreases in two fields (ID1 and ID5). Additionally, MYM treatment resulted in a significant decrease in total yield from the BMP treatment in the ID3 field, but marketable yield was not significantly different. This increase in yield resulted in a 1.3% non-significant increase in gross crop value (Figure 2). However, when the costs of the inputs were subtracted, a net loss of 3.2% was realized, which was significant at $P < 0.10$ (Figure 2). The results of these trials were given as an invited presented as part of the keynote symposium of the Potato Association of America annual meeting in 2005 and, as a part of this symposium, are being published in the American Journal of Potato Research (Hopkins et. al., 2006).

5.) The second annual "Advanced Potato Production Workshop" (featuring BMPs and crop, nutrient, soil, water, and pest management fundamentals) was conducted with 54 growers/agronomists in attendance (28 the first year). Several other workshops, where BMPs were presented/discussed, were presented over the course of the project with over 600 in attendance. In addition, eight field days were conducted to highlight the project and BMPs, with over 450 farmers, agronomists, and press in attendance. Furthermore, the results from this project have been disseminated in three UI news releases, and several trade journal and newspaper articles. BMPs and project findings are also published on a web page.

6.) Five farmer-to-farmer roundtable discussion groups with 61 participants have been conducted. The BMPs checklist was discussed, with suggestions for improvement from growers provided. Successes, failures, and roadblocks to adopting BMPs were also discussed. Additional roundtables are planned for 2007.

Impact of Results/Outcomes

This project has made substantial impacts on growers, agronomists, and the media. The University of Idaho Potato Cropping Systems Program has several projects, but more inquiries, from both the press and from growers, have been made in the last three years regarding this project than all others combined.

Over the course of three years, this Sustainable Potato project has been highlighted or discussed in: 1) ten interview articles in the popular press, 2) seven press releases, 3) two proceedings manuscripts, 4) seven radio interviews, 5) three extension newsletters, 6) five magazine articles, 7) three web pages, 8) five television interviews, 9) three regional, twenty-seven state, and four local grower meetings, including invited presentations at the Idaho, Oregon, and Washington potato conferences and field days, 10) one workbook, 11) four abstracts, 12) five grant progress reports, 13) three field day reports, 14) three posters, and 15) two volunteered and one invited presentation at international professional meetings, including invitation to publish a manuscript in the American Journal of Potato Research, along with the other invited presentations given at the keynote symposia at the Potato Association of America Annual Meetings in 2005.

More importantly, several individual growers and/or their farm managers/agronomists have met with the project leaders to have their farms evaluated for areas where improvements can be made (discussed in the Farmer Adoption section below). Judicious reductions in fertilizer and pesticide inputs have been documented on over 21,000 acres on eighteen farms, and grower meeting questionnaires indicate that changes on at least 75,000 acres are planned on other farms.

It is anticipated that a much larger number of acres will be impacted as interested farmers realize that they can produce an equivalent crop with less fertilizer and pesticide input. Many growers have expressed interest in this concept and seem to

agree in principle with the BMP approach. The problem for them is to overcome their feeling of safety with the status quo that has worked for them for many years. We are planning to work with a number of growers on a trial basis this coming year to enable them to try this change in management on a field or portion of a field. These efforts will reduce the overall risk potentially associated with excessive pesticide and fertilizer use, reduce risk of developing biological resistance to pesticides, and increase sustainability of both the land and the rural way of life.

Economic Analysis

The average gross crop value difference of MYM over BMP treatment was \$33 per acre (1.3%), but was not significantly different (Figure 2). However, there was a significant treatment by location interaction and differences between MYM and BMP treatments in individual fields were isolated for comparison. Not surprisingly, the fields showing significant differences in total yield (ID1, ID3, ID5, ID7, OR1, and WA1) also had significant differences in gross crop value (Figure 2). The gross crop values with MYM and BMP treatments in the remaining fields were statistically equivalent.

The average net crop value (factoring in cost of added inputs for MYM treatments) was not significantly different at $P < 0.05$ but was significantly different at $P < 0.10$, with a decrease of \$81 per acre with MYM treatment. As with gross crop value, the treatment by location interaction was significant and, therefore, the differences between MYM and BMP treatments in individual fields were isolated for comparison. The MYM treatment resulted in significant increases in just two of the fourteen fields (ID7 and WA1) (Figure 2). Five fields (ID1, ID3, ID5, and ID8 and OR3) had significant decreases in net crop value with MYM treatment. The net crop values with MYM and BMP treatments in the remaining fields were statistically equivalent.

The results of this project demonstrate that BMP growers are able to grow a similar crop with less cost and dollars at risk of loss than if they were to follow a maximum yield approach. As the “model” growers selected were believed to be among the better growers in the region, it is not surprising that their yields and tuber quality were mostly greater than local averages (Potato Stocks 2002, 2003, 2004, 2005). With regard to chemical inputs, the BMPs consist of using sampling, scouting, and prediction models to aid in determining input rate and timing. The BMPs center on a maximum economic yield approach, as determined by many research trials conducted over the past century (Hopkins et al., 2006). In contrast, the high input or MYM approach is typically based on tradition and calendar timing, with a near zero tolerance for pest and nutrient problems. The high input plots in this project received 1.7% to 13.2% more fertilizer and pesticide (cost basis) than the BMP plots in this study.

Although a simple marketable vs. cull comparison (common to processing potato contracts) was applied to these data, grower contracts and open market pay outs often take into account various combinations of incentives for specific gravity and US No. 1 and size percentages. The gross and net crop values reported would be different when incentives are applied. For example, incentives paid for higher percentages of US No. 1 tubers result in further separation from the already significant differences in gross and net crop values for the ID1, ID5, ID7, and OR1 fields. In these cases, the BMP treatment shows greater increases in crop value for the ID1 and ID5 fields, but the MYM treatment shows greater increases for the ID7 and OR1 fields. In contrast, the significant difference in crop value can be diminished (depending on the magnitude of the grade incentive) for the WA1 field, due to the fact that its increase in marketable tubers with MYM treatment was due to an increase in US No 2 and not US No. 1 tubers. Another example of a change in crop value is observed for the OR3 field, with the significant decrease in net crop value with MYM treatment potentially being nullified if a large enough incentive for tuber specific gravity were applied.

An infinite number of crop value scenarios could be applied to the data from this project. Indeed, many different base crop values and incentive adjustment scenarios were evaluated (data not shown). However, none of these scenarios resulted in an increase in net crop value for MYM over BMP treatment when averaging the results of all 14 fields. In fact, it took an improbable three to four fold increase in the average marketable and cull tuber pricing for the net crop value of the MYM treatment to break even with the BMP treatment. Furthermore, it took over a six fold increase in prices before the MYM treatment resulted in a significant increase in net crop value over the BMP treatment.

In addition, a higher cost of production represents more dollars at risk for growers. Although the average yield and gross crop value were statistically equivalent, this financial risk factor combined with the slightly significant decrease in net crop value, showed that the BMP approach is a superior management style over maximum yield management using higher inputs.

Publications/Outreach

International Presentations:

Hopkins, B.G., D.A. Horneck, M. Pavek, R. Thornton, G. Newberry, B.D. Geary, N. Olsen, and J.W. Ellsworth. November 9, 2005. Using On-Farm Demonstration to Promote Best Management Practices for Sustainable Potato Production. Agronomy – Crop – Soil Science Societies of America Annual Meeting. Salt Lake City, Utah.

Hopkins*, B.G., D. Horneck, M. Pavek, R. Thornton, and G. Newberry. July 18, 2005. Evaluation of University Best Management Practices (BMPs) in Potato Production. Invited Lecture. Best Management Practices for Nutrients and Irrigation: Research, Regulations and Future Directions. Potato Association of America Annual Meetings. Calgary, Alberta, Canada.

Regional Presentations:

Hopkins*, B.G., M. Pavek, R. Thornton, G. Newberry, and D. Horneck. February 3, 2005. Evaluation of University Best Management Practices (BMPs) in Potato Production. Invited Lecture. Washington Potato Conference. Moses Lake, Washington. (300 attendees)

State Presentations:

Hopkins*, B.G., D. Horneck, M. Pavek, R. Thornton, B. Geary, N. Olsen, J.W. Ellsworth, and G. Newberry. January 18, 2006. Evaluation of University Best Management Practices (BMPs) for Sustainable Potato Production. Invited Lecture. University of Idaho Potato Conference. (200 attendees anticipated)

Hopkins*, B.G., J.M. Alvarez, S.L. Hafez, P.J.S. Hutchinson, J.S. Miller, P.P. Patterson, and M. Thornton. June 28, 29, 30 and July 25, 26, 27; 2005. Potato Production Frequency BMPs. Invited Lecture. Trade Adjustment Assistance Training. Nine presentations given at Blackfoot, Burley, Idaho Falls, Pocatello, Rexburg, and Twin Falls; Idaho. (225 attendees)

Hopkins, B.G. February 17, 2005. Sustainable Large Scale Potato Production Program Review. University of Idaho Sustainable Ag Retreat. Caldwell, Idaho. (25 attendees)

Hopkins, B.G. January 6, 2005. Potato Cropping Systems Programming Update. University of Idaho Aberdeen R&E Center Faculty Staff Research Project Review. Aberdeen, Idaho. (30 attendees)

Hopkins, B.G. and J.W. Ellsworth. December 15, 2004. Soil, Water, and Nutrient Management Update (continued). Idaho Independent Crop Consultants. Aberdeen, Idaho. (9 attendees)

Hopkins, B.G. and J.W. Ellsworth. November 17, 2004. Soil, Water, and Nutrient Management Update. Idaho Independent Crop Consultants. Aberdeen, Idaho. (8 attendees)

Local Presentations:

Hopkins, B.G. October 21, 2005. Best Management Practices in Potato Production. Shoshone-Bannock Tribe & NCAP Green Manure Field Day. Fort Hall, Idaho. (50 attendees)

Refereed Publications:

Hopkins, B.G., D.A. Horneck, M.J. Pavek, B.D. Geary, N.L. Olsen, J.W. Ellsworth, G.D. Newberry, J.S. Miller, and R.E. Thornton, and G.W. Harding. 2006. Potato Production Best Management Practices. *Am. J. Potato Res.* (invited and in review).

Peer Reviewed Bulletins:

Hopkins, B.G., D.A. Horneck, M.J. Pavek, B.D. Geary, N.L. Olsen, J.W. Ellsworth, G.D. Newberry, J.S. Miller, and R.E. Thornton, and G.W. Harding. 2006. Sustainable Potato Production Best Management Practices. *Univ. Idaho Ag. Com. PNW Bulletin* (submitted).

Proceedings:

Hopkins, B.G., B.D. Geary, J.W. Ellsworth, N. Olsen, D.A. Horneck, M. Pavek, G. Newberry, and R. Thornton. 2005.

Best Management Practices for Potato Production. p. 31-34 In A. Jensen (ed.) Proceedings of the 44th Annual Washington State Potato Conference. Washington State Potato Commission, Moses Lake, Washington.

Hopkins, B.G., P.P. Patterson, P.J.S. Hutchinson, J.S. Miller, M. Thornton, S.L. Hafez, and J.M. Alvarez. 2005. Cropping Sequence and Rotation: Impact on Potato Production and Soil Condition. Trade Adjustment Assistance Training Workshop Workbook. University of Idaho. Moscow, Idaho.

Abstracts:

Hopkins, B.G. 2005. Sustainable Potato Cropping Systems. Abstract. University of Idaho Sustainable Ag Retreat.

Hopkins, B.G., D.A. Horneck, M. Pavek, R. Thornton, G. Newberry, B.D. Geary, N. Olsen, and J.W. Ellsworth. 2005. Best Management Practices for Sustainable Potato Production: Putting University Recommendations to the Test. (S4). Potato Association of America Annual Meeting Published Abstracts. Calgary, Alberta, Canada.

Hopkins, B.G., D.A. Horneck, M. Pavek, R. Thornton, G. Newberry, B.D. Geary, N. Olsen, and J.W. Ellsworth. 2005. Using On-Farm Demonstration to Promote Best Management Practices for Sustainable Potato Production. Agronomy – Crop – Soil Science Societies of America Annual Meeting Abstracts.

Newsletters:

Fritz, M. and B.G. Hopkins. 2006. Model Potato Growers Maximize Profits through Best-Management Practices. Ag Knowledge. University of Idaho. Moscow, Idaho (In Review).

Fritz, M. and B.G. Hopkins. March 2005. Best Management Practices for Potato Production. Extension Trends. University of Idaho. Moscow, Idaho.

Web pages:

Hopkins, B.G. 2005. Best Management Practices for Sustainable Potato Production Field Day web page. <http://extension.ag.uidaho.edu/bhopkins/Field%20days/2004/bmppage.htm>

Hopkins, B.G. 2005. Best Management Practices for Sustainable Potato Production web page. <http://extension.ag.uidaho.edu/bhopkins/Projects/bmp.htm>

Hopkins, B.G., J.C. Stark, S.L. Hafez, P.J.S. Hutchinson, P. Patterson, J. Miller, M. Thornton, and J.M. Alvarez. 2005. Field Selection, Crop Rotations, and Soil Management web page. <http://www.ag.uidaho.edu/potato/production/files/soil%20management%20and%20crop%20rotation%20and%20sequence.pdf>

Hopkins, B.G., J.C. Stark, D.T. Westermann, and J.W. Ellsworth. 2005. Nutrient Management web page. <http://www.ag.uidaho.edu/potato/production/files/NUTRIENT%20MANAGEMENT.pdf>

News releases, newspaper articles, etc.:

Fischbach, S. August 5, 2005. Wanted: Research Growers Can Use. Interview Article. Intermountain Farm and Ranch 679:3,10. Idaho Falls, Idaho.

Scott, B. July 27, 2005. Spud growers BMP field day. Phone interview for radio based news program – 64 stations. Today's Ag Radio News – The Northwest Ag Information Network. Boise, Idaho.

Anonymous. July 22, 2005. 'Famous Potatoes Day' to Yield New Data. Interview Article. Intermountain Farm and Ranch 677:5. Idaho Falls, Idaho.

Fritz, M. and B.G. Hopkins. June 30, 2005. Mini Potato Conference Under the Sun. University of Idaho Press Release.

Scott, B. May 20, 2005. Potato Rotations. Today's Idaho Ag News. Interview quotes broadcasted on 64 radio stations.

Articles in magazines, trade journals, etc:

Hopkins, B.G., E. Cook, and R. Neff. July 2005. Famous Potatoes Field Day. *Potato Grower* 34(7):29-31, 37. Harris Publishing, Idaho Falls, Idaho.

Fairbourn, D. November 2004. U of I Researchers Compare Management Practices. Interview article. *Potato Grower* 33(11):24-27. Harris Publishing, Idaho Falls, Idaho.

Farmer Adoption

Several individual growers and/or their farm managers/agronomists have met with the project leader to have their farms evaluated for areas where improvements can be made. Judicious reductions in fertilizer and pesticide inputs have been documented on over 21,000 acres on eighteen farms and grower meeting questionnaires indicate that changes on at least 75,000 acres are planned on other farms. This represents over one-third of the potato acres in Idaho.

It is anticipated that a much larger number of acres will be impacted as interested farmers realize that they can produce an equivalent crop with less fertilizer and pesticide input. In fact, many more undocumented changes are likely. Many growers have expressed interest in this concept and seem to agree in principle with the BMP approach. The problem for them is to overcome their feeling of safety with the status quo that has worked for them for many years. We are planning to work with a number of growers on a trial basis this coming year to enable them to try this change in management on a field or portion of a field. These efforts will reduce the overall risk potentially associated with excessive pesticide and fertilizer use, reduce risk of developing biological resistance to pesticides, and increase sustainability of both the land and the rural way of life.

In general, it is suggested that growers apply fertilizer and pesticides based on research findings, with application date(s) and rates determined by maximum economic yield rather than maximum yield. Scouting and sampling/analysis, as well as due attention to local pest/pathogen pressure and forecasting models, provide a basis for application of inputs. This is in contrast to applications based on tradition and/or calendar timing that is common for many farm managers. An exhaustive list of the BMPs recommended for the day-to-day farm operations is found in the PNW bulletin listed above.

Areas Needing Additional Study

Evaluation of conventional potato BMPs needs to be continually studied and revised. One particularly bad problem is the very short length of time between potato crops in much of the Pacific Northwest. The time between potato crops is often only two years, apparently resulting in relatively higher pest/pathogen populations and an increased dependence on pesticides. A Western SARE-funded project is currently underway to study and educate regarding this problem.

Furthermore, demand for organic food stuffs is increasing over 20% per year and demand for organic potatoes is no exception (Keith Esplin, President of Potato Growers of Idaho, personal communication). Existing organic potato production methods need to be evaluated and demonstrated. New methods need to be developed and evaluated to enable growers to grow potatoes in the absence of pesticides and traditional fertilizers to support the increasing demand for organic potato production. Specific organic potato production research needs include: 1) biodegradable corn starch based matting for weed control, 2) uniform plant spacing in beds for weed suppression, 3) modified cultivation for weed suppression, 4) "beetle banks" for biological pest control, 5) reduced tillage for improved soil quality and weed/pathogen suppression, 6) drip irrigation for reduced foliar wetness and risk of various pathogens such as late blight, 7) legume and organic fertilizer use for potato nutrition, and 8) organic pesticides for control of weeds, insects, nematodes, and pathogens. Also, organic fields need to be established as models for potato growers to follow. There is a rapidly growing interest among growers to capitalize on the burgeoning organic specialty market, but this form of production is a very foreign concept to most and their comfort level in adopting these practices would be facilitated by actual production with associated field days and training (Keith Esplin, President of Potato Growers of Idaho, personal communication). A more comprehensive listing of the research, education, and regulatory needs for organic potato production is currently being developed through the Pest Management Strategic Planning program (Ronda Hirnyck, pesticide coordinator, University of Idaho, personal communication).